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(54) **COMMUNICATION NODE, COMMUNICATION SYSTEM AND OPERATING METHOD THEREOF**

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(57)   **ABSTRACT**

Provided are a method of operating a communication system using physical layer division, the method comprises extracting an initial random access signal from an uplink signal, in a first physical layer of a first communication node of the communication system reducing a data amount of the extracted initial random access signal in the first physical layer and calculating a time synchronization error using the initial random access signal with a reduced amount of data,
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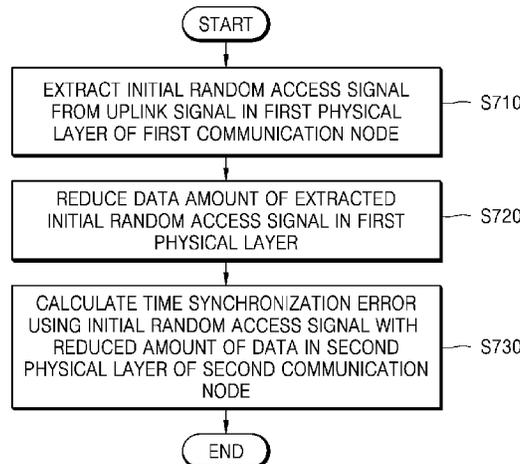
in a second physical layer of a second communication node of the communication system.

11 Claims, 7 Drawing Sheets

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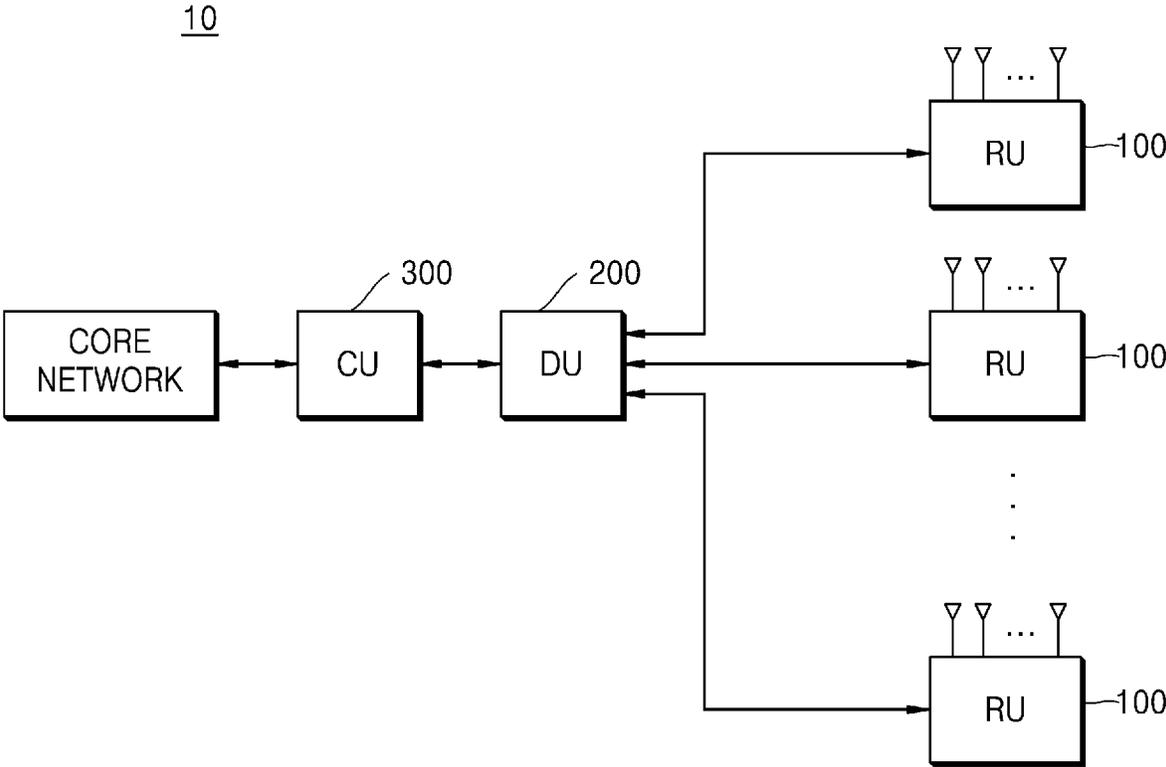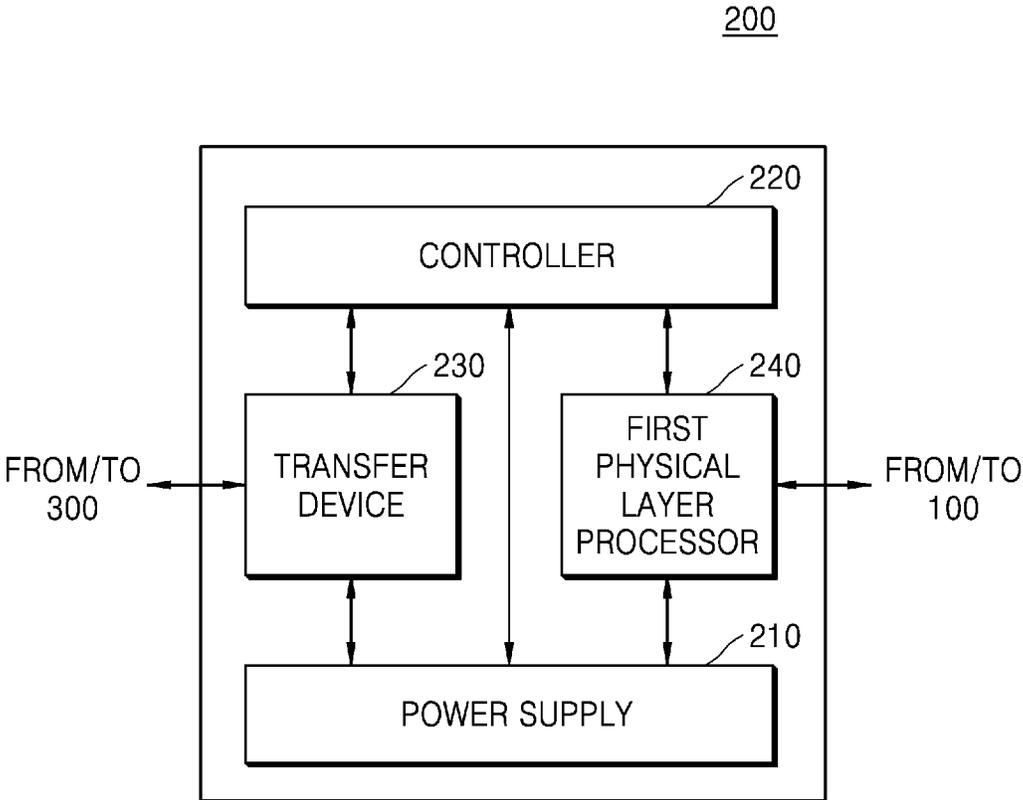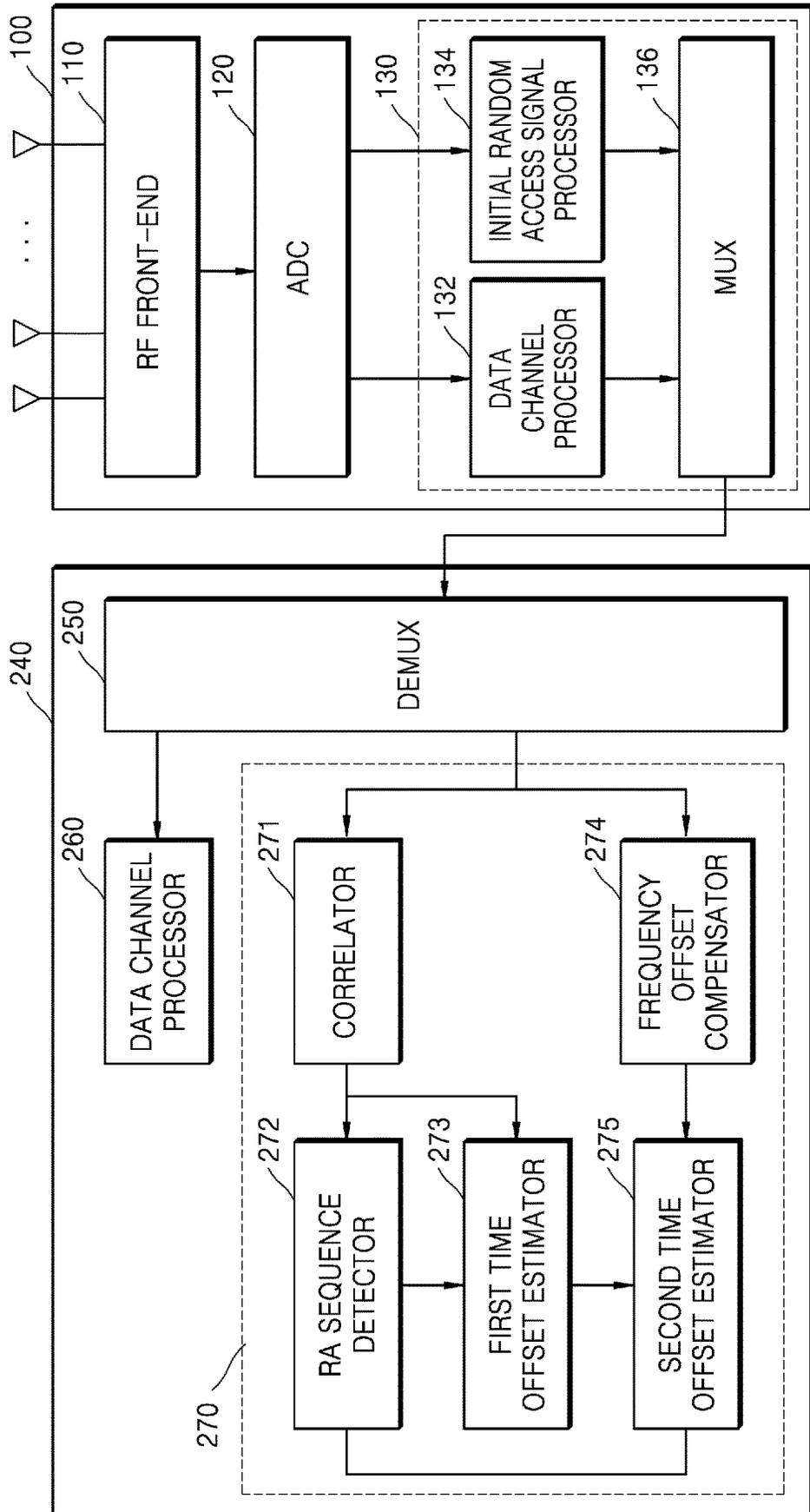
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FIG. 1

10

FIG. 2

<u>200</u>

FIG. 3

FIG. 4

$x(n) \longrightarrow \bigotimes \xrightarrow{x_B(n)}$ 134-1

Lowpass Filter h(n)   134-2

$\xrightarrow{y(n)}$ $L\downarrow$ 134-3 $\xrightarrow{y_D(m)}$

$e^{-\dfrac{j2\pi f_{RA}n}{N}}$

FIG. 5

FIG. 6

FIG. 7

START

EXTRACT INITIAL RANDOM ACCESS SIGNAL FROM UPLINK SIGNAL IN FIRST PHYSICAL LAYER OF FIRST COMMUNICATION NODE — S710

REDUCE DATA AMOUNT OF EXTRACTED INITIAL RANDOM ACCESS SIGNAL IN FIRST PHYSICAL LAYER — S720

CALCULATE TIME SYNCHRONIZATION ERROR USING INITIAL RANDOM ACCESS SIGNAL WITH REDUCED AMOUNT OF DATA IN SECOND PHYSICAL LAYER OF SECOND COMMUNICATION NODE — S730
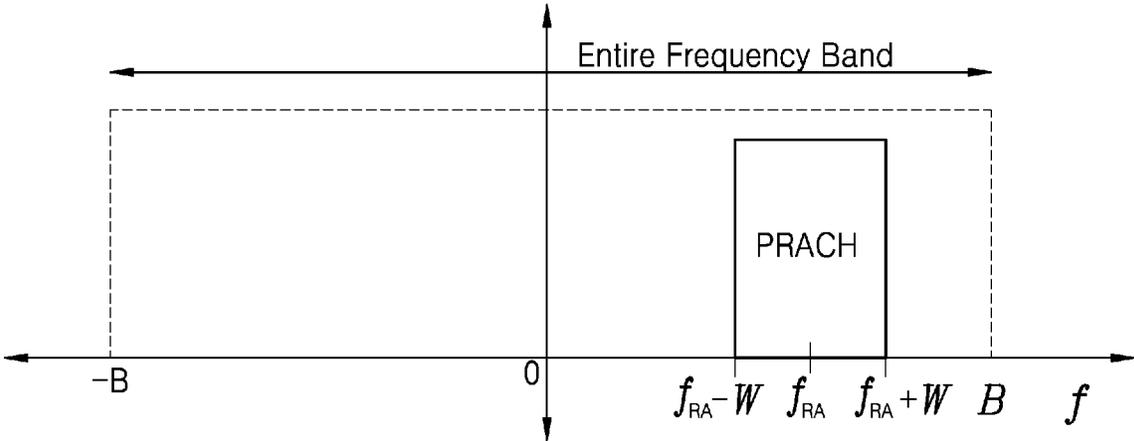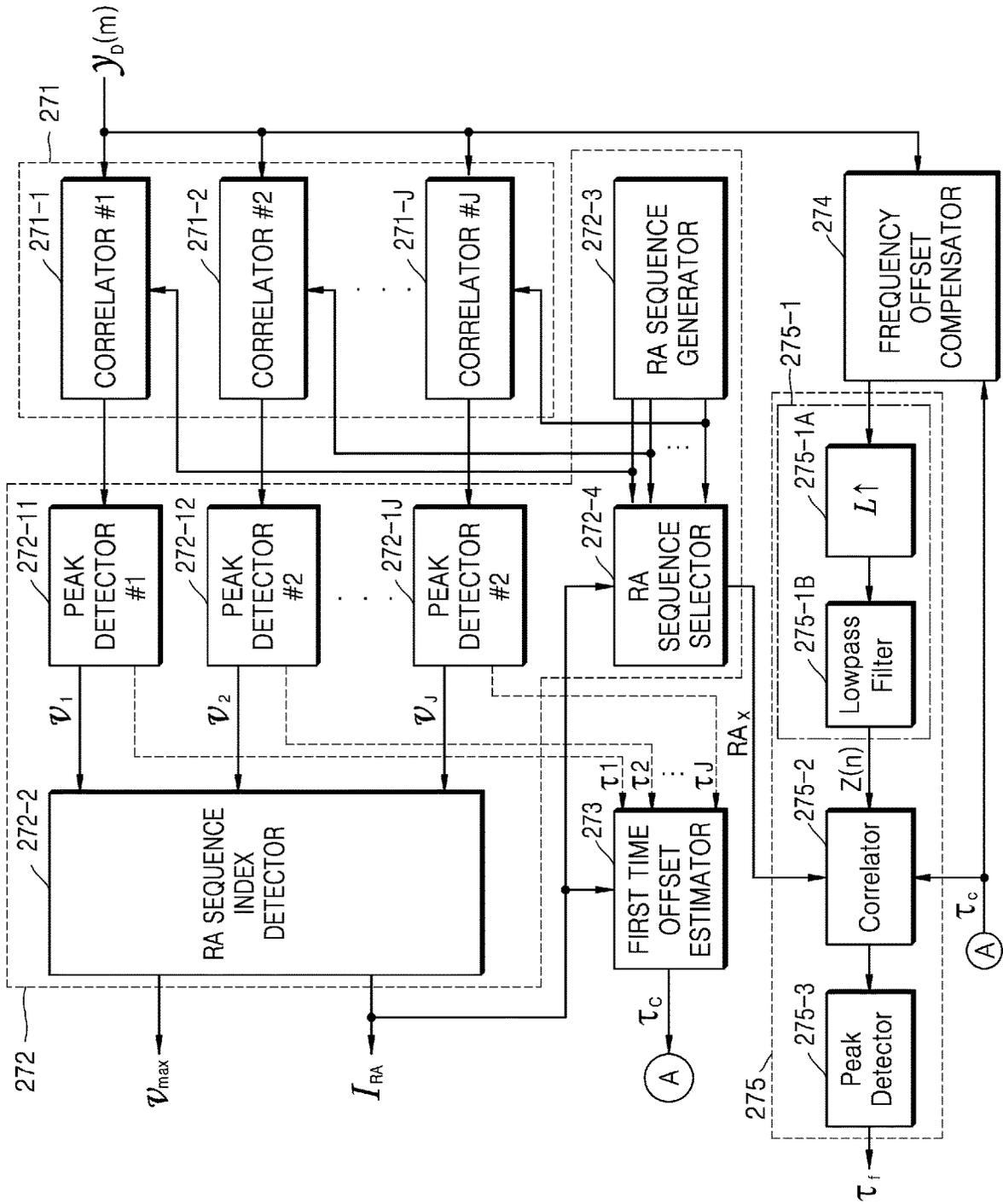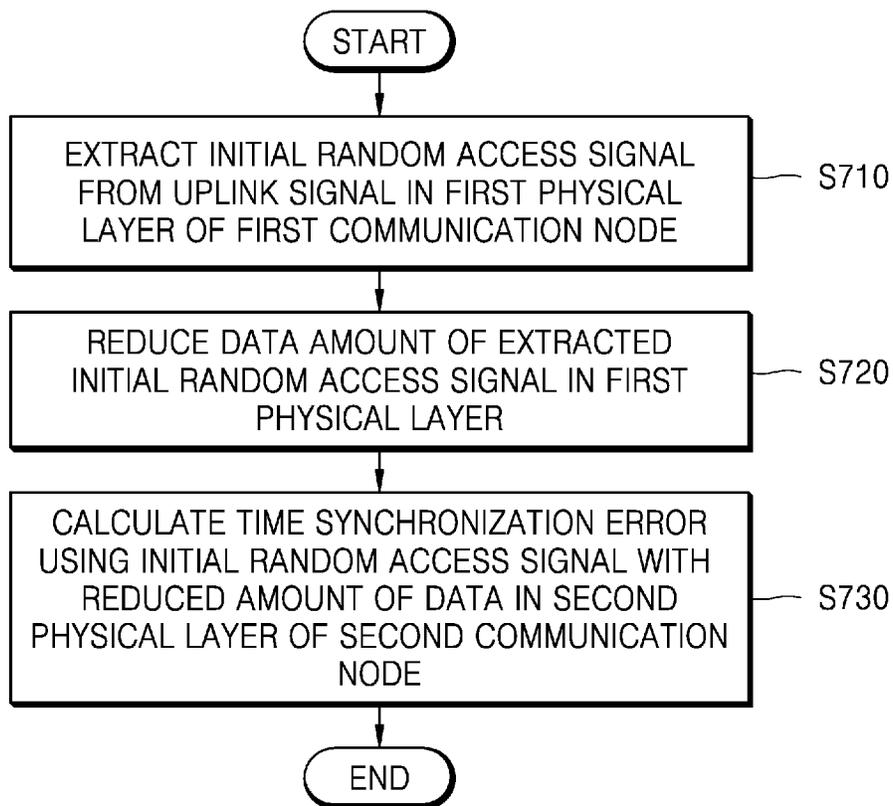
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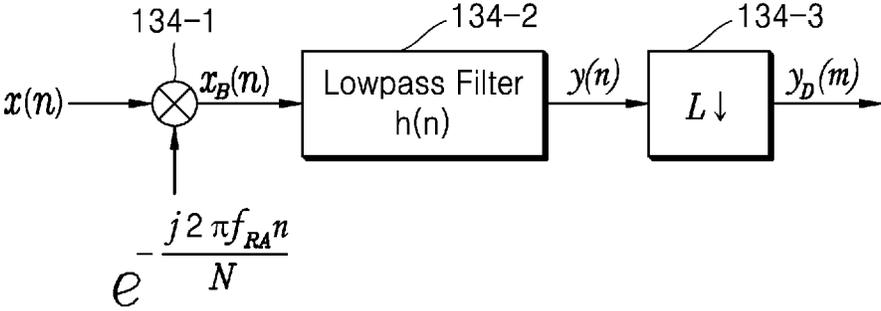
COMMUNICATION NODE, COMMUNICATION SYSTEM AND OPERATING METHOD THEREOF

CROSS REFERENCE TO RELATED APPLICATIONS

This application is a National Stage of International Application No. PCT/KR2020/016476, filed Nov. 20, 2020, claiming priority to Korean Patent Application No. 10-2019-0152580, filed Nov. 25, 2019 and Korean Patent Application No. 10-2020-0156047, filed Nov. 19, 2020.

TECHNICAL FIELD

The present invention relates to a communication node, a communication system, and a method of operating the same, and more particularly, to a communication node capable of receiving an initial random access signal with a reduced amount of data extracted from an uplink signal in a first physical layer from another communication node and calculating a time synchronization error using the initial random access signal with the reduced amount of data in a second physical layer, a communication system, and a method of operating the same.

BACKGROUND ART

In the existing mobile communication system, in order to provide a communication service to a base station shadow area such as a building or subway, a distributed antenna structure is constructed with a remote wireless device, and the remote wireless device and a digital device of a base station are connected to each other using a matching unit.

In particular, when implementing a distributed antenna system in a 5G mobile communication system, there is a limit to installing an additional dedicated cable for 5G communication, so the cable installed for 3G/4G communication is often shared. However, there is a problem that the cable installed for 3G/4G communication has insufficient capacity to support the maximum transmission speed defined in the 5G standard specification.

DESCRIPTION OF EMBODIMENTS

Technical Problem

The present invention provides a communication node capable of receiving an initial random access signal with a reduced amount of data extracted from an uplink signal in a first physical layer from another communication node and calculating a time synchronization error using an initial random access signal with a reduced amount of data in a second physical layer, a communication system, and a method of operating the same.

Solution to Problem

According to an aspect of an embodiment, a method of operating a communication system using physical layer division may comprise extracting an initial random access signal from an uplink signal, in a first physical layer of a first communication node of the communication system, reducing a data amount of the extracted initial random access signal in the first physical layer and calculating a time synchronization error using the initial random access signal

with a reduced amount of data, in a second physical layer of a second communication node of the communication system.

According to an aspect of an embodiment, the first physical layer may be a lower physical layer according to the physical layer division, and the second physical layer may be an upper physical layer according to the physical layer division.

According to an aspect of an embodiment, the initial random access signal may be a physical random access channel (PRACH) signal.

According to an aspect of an embodiment, the first communication node may be a remote unit, and the second communication node may be a distributed unit.

According to an aspect of an embodiment, the extracting of the initial random access signal from the uplink signal may comprise shifting a frequency band of the uplink signal to a baseband and extracting the initial random access signal by low-pass filtering the frequency band-shifted uplink signal.

According to an aspect of an embodiment, the reducing of the data amount of the extracted initial random access signal may comprise downsampling the extracted initial random access signal to reduce the data amount of the initial random access signal.

According to an aspect of an embodiment, the method may further comprise transmitting a combined signal generated by combining the uplink signal through data channel processing of the first physical layer in the first communication node and the initial random access signal with the reduced amount of data to the second communication node, and the calculating of the time synchronization error may comprise separating the initial random access signal with the reduced amount of data from the combined signal and calculating a time synchronization error using the separated initial random access signal with the reduced amount of data.

According to an aspect of an embodiment, the calculating of the time synchronization error may comprise calculating a first time offset using the initial random access signal with the reduced amount of data, restoring an initial random access signal with an original amount of data by using the initial random access signal with the reduced amount of data and calculating a second time offset using the first time offset and the restored initial random access signal.

According to an aspect of an embodiment, the calculating of the first time offset may comprise calculating a correlation value between the initial random access signal with the reduced amount of data and a plurality of random access sequences, searching for a random access sequence having a maximum correlation value from among the plurality of random access sequences and calculating the first time offset using the searched random access sequence having the maximum correlation value.

According to an aspect of an embodiment, the restoring of the initial random access signal with the original amount of data may comprise upsampling the initial random access signal with the reduced amount of data and interpolating the upsampled initial random access signal.

According to an aspect of an embodiment, the interpolating of the upsampled initial random access signal may comprise low-pass filtering the upsampled initial random access signal.

According to an aspect of an embodiment, the calculating of the second time offset using the first time offset and the restored initial random access signal may comprise calculating the second time offset using the first time offset, the

restored initial random access signal, and the random access sequence having the maximum correlation value.

According to an aspect of an embodiment, the calculating of the second time offset using the first time offset, the restored initial random access signal, and the random access sequence having the maximum correlation value may comprise calculating the second time offset based on a point at which a correlation value of the restored initial random access signal and the random access sequence having the maximum correlation value becomes maximum within a reference range from the first time offset.

According to an aspect of an embodiment, a communication node may include a memory and a processor, wherein the communication node, in a first physical layer of another communication node, may receive an initial random access signal with a reduced amount of data extracted from an uplink signal from the other communication node, and calculate a time synchronization error using the initial random access signal with the reduced amount of data in a second physical layer of the communication node.

According to an aspect of an embodiment, a communication system using physical layer division may comprise a first communication node configured to extract an initial random access signal from an uplink signal and reducing a data amount of the extracted initial random access signal in a first physical layer and a second communication node configured to calculate a time synchronization error using the initial random access signal with a reduced amount of data in a second physical layer.

Advantageous Effects of Disclosure

A method and a device according to an embodiment of the present invention have an advantage in that the capacity of data (e.g., a physical random access channel (PRACH) signal) required to be transmitted between communication nodes may be reduced in a process of calculating a time synchronization error, and at the same time, because the time synchronization error is estimated in an upper physical layer, information for calculating the time synchronization error (e.g., information about random access sequences, etc.) does not need to be shared with a lower physical layer.

BRIEF DESCRIPTION OF DRAWINGS

A brief description of each drawing is provided to more fully understand drawings recited in the detailed description of the present invention.

FIG. 1 is a conceptual diagram of a communication system according to an embodiment of the present invention.

FIG. 2 is a block diagram of a distributed unit shown in FIG. 1.

FIG. 3 is a block diagram of a first physical layer processor and a remote unit of the distributed unit shown in FIG. 1.

FIG. 4 is an embodiment of an initial random access signal processor included in a second physical layer processor shown in FIG. 3.

FIG. 5 is an embodiment of an initial random access signal included in an uplink signal.

FIG. 6 is an embodiment of a time synchronization error detector included in the first physical layer processor shown in FIG. 3.

FIG. 7 is a flowchart illustrating a method of operating a communication system according to an embodiment of the present invention.

MODE OF DISCLOSURE

The inventive concept may be variously modified and have various embodiments, so that specific embodiments will be illustrated in the drawings and described in the detailed description. However, this does not limit the inventive concept to specific embodiments, and it should be understood that the inventive concept covers all the modifications, equivalents and replacements included within the idea and technical scope of the inventive concept.

In describing the inventive concept, in the following description, a detailed explanation of known related technologies may be omitted to avoid unnecessarily obscuring the subject matter of the present disclosure. In addition, numeral figures (e.g., 1, 2, and the like) used during describing the specification are just identification symbols for distinguishing one element from another element.

Further, in the specification, if it is described that one component is "connected" or "accesses" the other component, it is understood that the one component may be directly connected to or may directly access the other component but unless explicitly described to the contrary, another component may be "connected" or "access" between the components.

In addition, terms including "unit," "er," "or," "module," and the like disclosed in the specification mean a unit that processes at least one function or operation and this may be implemented by hardware or software such as a processor, a micro processor, a micro controller, a central processing unit (CPU), a graphics processing unit (GPU), an accelerated Processing unit (APU), a digital signal processor (DSP), an application specific integrated circuit (ASIC), and a field programmable gate array (FPGA) or a combination of hardware and software. Furthermore, the terms may be implemented in a form coupled to a memory that stores data necessary for processing at least one function or operation.

Moreover, it is intended to clarify that components in the specification are distinguished in terms of primary functions of the components. That is, two or more components to be described below may be provided to be combined to one component or one component may be provided to be divided into two or more components for each more subdivided function. In addition, each of the respective components to be described below may additionally perform some or all functions among functions which other components take charge of in addition to a primary function which each component takes charge of and some functions among the primary functions which the respective components take charge of are exclusively charged by other components to be performed, of course.

FIG. 1 is a conceptual diagram of a communication system according to an embodiment of the present invention.

Referring to FIG. 1, a communication system 10 according to an embodiment of the present invention may include a plurality of remote units (RUs) 100, a distributed unit (DU) 200, a centralized unit (CU) 300, and a core network.

The plurality of remote units 100 may be connected to the distributed unit 200 and distributed to transmit and receive signals transmitted/received from a base station at locations distributed in various shaded areas or dense areas.

The communication system 10 according to an embodiment of the present invention may use physical layer division between the plurality of remote units 100 and the distributed unit 200. The plurality of remote units 100 may

process a lower physical layer (Low-PHY), and the distributed unit 200 may process an upper physical layer (High-PHY).

According to an embodiment, the plurality of remote units 100 and the distributed unit 200 may be connected to each other through various communication media such as optical cables, high-speed cables, or microwave cables.

According to an embodiment, the plurality of remote units 100 and the distributed unit 200 may conform to various fronthaul communication standards. For example, an Ethernet-based Common Public Radio Interface (eCPRI), which is a 5G fronthaul interface standard, may be used between the plurality of remote units 100 and the distributed unit 200.

The base station may be divided into the distributed unit 200 and the centralized unit 300, wherein the distributed unit 200 and the centralized unit 300 may separate functions in various forms according to various function split options (e.g., 3GPP TR38.801 standard, etc.).

According to an embodiment, the distributed unit 200 and the centralized unit 300 may divide and process layers into RRC, PDCP, High-RLC, Low-RLC, High-MAC, Low-MAC, and High-PHY.

FIG. 1 illustrates a structure in which the base station is divided into the distributed unit 200 and the centralized unit 300, but is not limited thereto, and various modifications are possible.

The centralized unit 300 may directly work with a core network, and may interface between the core network and the base station.

Detailed structures and operations of the remote unit 100 and the distributed unit 200 will be described later with reference to FIGS. 2 to 7.

FIG. 2 is a block diagram of the distributed unit shown in FIG. 1.

Referring to FIGS. 1 and 2, the distributed unit 200 may include a power supply 210, a controller 220, a transfer device 230, and a first physical layer processor 240.

The power supply 210 may supply power to components (e.g., 220 to 240) in the distributed unit 200.

The controller 220 may control all operations of the components (e.g., 210, 230, and 240) in the distributed unit 200.

The transfer device 230 may interface communication between the distributed unit 200 and the centralized unit 300, and may perform signal processing necessary for signal transmission/reception with the centralized unit 300.

The first physical layer processor 240 may process functions supported by the first physical layer (e.g., the upper physical layer (High-PHY)).

Detailed structure and operation of the first physical layer processor 240 will be described later with reference to FIGS. 3 and 5.

FIG. 3 is a block diagram of a first physical layer processor and a remote unit of the distributed unit shown in FIG. 1. FIG. 4 is an embodiment of an initial random access signal processor included in a second physical layer processor shown in FIG. 3. FIG. 5 is an embodiment of an initial random access signal included in an uplink signal. FIG. 6 is an embodiment of a time synchronization error detector included in the first physical layer processor shown in FIG. 3.

Referring to FIGS. 1 to 3, the remote unit 100 may include an RF front-end 110, an analog-to-digital converter (ADC) 120, and a second physical layer processor 130.

The remote unit 100 may convert an uplink signal of an RF band received through an antenna into a baseband signal through the RF front-end 110.

The ADC 120 may convert an analog baseband signal converted by the RF front-end 110 into a digital signal.

The ADC 120 may transmit the converted digital signal to the second physical layer processor 130.

The second physical layer processor 130 may include a data channel processor 132, an initial random access signal processor 134, and a multiplexer (MUX) 136.

The second physical layer processor 130 may process a portion of a physical layer (e.g., the lower physical layer (low-PHY)) divided in the communication system 10 using physical layer division.

The data channel processor 132 may process a data channel of a digitally converted uplink signal. According to an embodiment, the data channel processor 132 may perform processing such as cyclic prefix (CP) removal, discrete Fourier transform (DFT), and data compression on the uplink signal.

The initial random access signal processor 134 may extract an initial random access signal from the digitally converted uplink signal and reduce a data amount of the extracted initial random access signal.

According to an embodiment, the initial random access signal may be a Physical Random Access Channel (PRACH) signal.

Referring to FIG. 4 together, the initial random access signal processor 134 may include a mixer 134-1, a low pass filter 134-2, and a down sampler 134-3.

The mixer 134-1 may receive an uplink signal x(n) that is digitally converted and transmitted by the ADC 120, and may shift a frequency band of the received uplink signal x(n) to the baseband.

The input signal x(n) and an output signal xb(n) input/output by the mixer 134-1 may be expressed by the relationship of Equation 1 below.

$$x_B(n) = x(n)e^{-\frac{j2\pi f_{RA}n}{N}} \quad \text{(Equation 1)}$$

(where N is a DFT size when using orthogonal frequency division multiplexing (OFDM), and n is a time index of a sample)

Referring to FIG. 5 together, in an uplink signal, a frequency band in which an initial random access signal (e.g., a PRACH signal) is located is shown, a center frequency is f_{RA}, and a bandwidth from the center frequency to both ends of the frequency band is denoted by W.

The mixer 134-1 may frequency shift the uplink signal (e.g., the PRACH signal) so that the center frequency of the initial random access signal becomes zero.

The low-pass filter 134-2 may perform low-pass filtering so that only the frequency band in which the initial random access signal (e.g., the PRACH signal) exists in the uplink signal in which the frequency band is shifted to a baseband by the mixer 134-1 passes through.

The low-pass filter 134-2 may extract only the initial random access signal (e.g., the PRACH signal) from the uplink signal through the low-pass filtering and output the initial random access signal as an output signal y(n).

In this case, the output signal y(n) may be expressed as in Equation 2 below.

$$y(n) = \sum_{m=0}^{N_{LPF}-1} h(m)x_B(n-m) \quad \text{(Equation 2)}$$

(where h(n) is an impulse response of the low-pass filter **134-2**, and N_{LPF} is the number of taps of the low-pass filter **134-2**)

According to an embodiment, a range of a pass band of the low pass filter **134-2** may be set according to a frequency range of the initial random access signal (e.g., the PRACH signal) frequency shifted to a baseband.

Returning to FIG. **4**, the down-sampler **134-3** down-samples the output signal y(n) filtered by the low-pass filter **134-2** to output an initial random access signal $y_D(m)$ with a reduced amount of data.

According to an embodiment, the down-sampler **134-3** may downsample the output signal y(n) filtered by the low-pass filter **134-2** by L times and output the output signal y(n). In this case, the output signal may be expressed as in Equation 3 below.

$$y_D(m)=y(mL+\alpha) \qquad \text{(Equation 3)}$$

(where m is an integer indicating a time index after downsampling, L is an integer satisfying $1 \geq L \geq /W$, and α is an integer value satisfying $1 \geq \alpha \geq L-1$, which is a downsampling offset)

According to an embodiment, the down sampler **134-3** may be modified to reduce the amount of data in various ways (e.g., a compressor for compressing data, etc.).

Returning to FIG. **3**, the multiplexer **136** may combine an uplink signal processed and output by the data channel processor **132** and an initial random access signal extracted by the initial random access signal processor **134** to reduce the amount of data to generate a combined signal, and may output the generated combined signal.

According to an embodiment, the multiplexer **136** may combine the uplink signal processed and output by the data channel processor **132** and the initial random access signal extracted by the initial random access signal processor **134** to reduce the amount of data into a single data stream.

The multiplexer **136** may transmit the combined signal to the first physical layer processor **240**.

The first physical layer processor **240** may include a demultiplexer (DEMUX) **250**, a data channel processor **260**, and a time synchronization error detector **270**.

The demultiplexer **250** may separate an initial random access signal with a reduced amount of data from the combined signal transmitted from the multiplexer **136** of the second physical layer processor **130**.

The demultiplexer **250** may transmit the uplink signal that has been processed and output by the data channel processor **132** of the second physical layer processor **130** to the data channel processor **260** of the first physical layer processor **240**, and the initial random access signal with a reduced amount of data may be transmitted to the time synchronization error detector **270**.

The data channel processor **260** may receive the uplink signal that has been processed and output by the data channel processor **132** of the second physical layer processor **130** to perform data channel processing in the first physical layer.

According to an embodiment, the data channel processor **260** may perform various processes such as demodulation, demapping, and data decompression on the uplink signal.

The time synchronization error detector **270** may include a correlator **271**, a random access (RA) sequence detector **272**, a first time offset estimator **273**, a frequency offset compensator **274**, and a second time offset estimator **275**.

The correlator **271** may calculate a correlation value between a plurality of initial random access signals with a reduced amount of data and a plurality of random access sequences.

The random access sequence detector **272** may search for a random access sequence having a maximum correlation value from among the plurality of random access sequences, and may output information about the maximum correlation value and a random access sequence corresponding thereto (e.g., an index) according to a search result.

The first time offset estimator **273** may calculate a first time offset using a random access sequence having the maximum correlation value.

The frequency offset compensator **274** may estimate a frequency offset of a received initial random access signal and compensate the estimated frequency offset to output an initial random access signal in which the frequency offset is compensated.

The second time offset estimator **275** may calculate the first time offset output by the first time offset estimator **273**, a restored initial random access signal obtained by restoring the initial random access signal with a reduced amount of data, and a second time offset using the random access sequence having the maximum correlation value.

For description of the detailed structure and operation of the time synchronization error detector **270**, referring to FIG. **6**, the correlator **271** may include a plurality of correlators **271-1** to **271-J**.

Each of the plurality of correlators **271-1** to **271-J** (where J is an integer of 2 or more) may calculate and output a correlation value between each of a plurality of random access sequences generated by a random access sequence generator **272-3** and the initial random access signal $y_D(m)$ with a reduced amount of data.

The random access sequence detector **272** may include a plurality of peak detectors **272-11** to **272-1J**, a random access sequence index detector **272-2**, the random access sequence generator **272-3**, and a random access sequence selector **272-4**.

The plurality of peak detectors **272-11** to **272-1J** may detect and output maximum correlation values V1 to VJ from correlation values output from the plurality of correlators **271-1** to **271-J**, respectively.

The plurality of peak detectors **272-11** to **272-1J** may detect and output time values τ_1 to τ_J with respect to points corresponding to the maximum correlation values V1 to VJ from the correlation values output from the plurality of correlators **271-1** to **271-J**, respectively.

The random access sequence index detector **272-2** may detect a largest correlation value Vmax from among the maximum correlation values V1 to VJ by using the maximum correlation values V1 to VJ respectively output from the plurality of peak detectors **272-11** to **272-1J**, and output an index value I_{RA} of a random access sequence corresponding to the largest correlation value Vmax.

The random access sequence generator **272-3** may generate and output a plurality of random access sequences that are candidates.

The random access sequence selector **272-4** may select and output a random access sequence corresponding to the index value I_{RA} of the random access sequence having the largest correlation value Vmax from among the plurality of random access sequences generated by the sequence generator **272-3**.

The first time offset estimator **273** may receive the time values τ_1 to τ_J from the plurality of peak detectors **272-11** to **272-1J**, receive the index value I_{RA} from the random access

sequence index detector **272-2**, and calculate the time value τ_c corresponding to the index value I_{RA} from among the time values τ_1 to τ_J as the first time offset.

The frequency offset compensator **274** may estimate and compensate the frequency offset using the first time offset τ_c 5 calculated by the first time offset estimator **273** and a repetition characteristic of an initial random access signal (e.g., the PRACH signal) in a time domain.

The second time offset estimator **275** may include a signal restorer **275-1**, a correlator **275-2**, and a peak detector **275-3**. 10

The signal restorer **275-1** may include an up-sampler **275-1A** and a low-pass filter **275-1B**.

The up-sampler **275-1A** may upsample an initial random access signal with a reduced amount of data.

According to an embodiment, the up-sampler **275-1A** 15 may perform upsampling by L times corresponding to a multiple of reducing a data amount of the initial random access signal in a second physical layer.

The low-pass filter **275-1B** may perform interpolation processing on the upsampled initial random access signal by 20 low-pass filtering the upsampled initial random access signal.

According to an embodiment, an interpolated signal in the time domain may be obtained by performing low-pass filtering on the upsampled initial random access signal after 25 converting the upsampled initial random access signal to a frequency domain using N-point DFT before the low-pass filtering of the low-pass filter **275-1B**, and applying the N-point IDFT to the low-pass filtered signal.

According to an embodiment, an interpolation method of 30 the upsampled initial random access signal may be variously modified, such as nearest neighbor interpolation, linear interpolation, quadratic interpolation, cubic interpolation, and cubic interpolation for each section.

An initial random access signal with a reduced amount of 35 data through processing of the up-sampler **275-1A** and the low-pass filter **275-1B** may be restored to the initial random access signal with the original amount of data.

The correlator **275-2** and the peak detector **275-3** may calculate the second time offset based on the first time offset 40 τ_c, a restored initial random access signal z(n), and a random access sequence RA_X having a maximum correlation value.

The correlator **275-2** may calculate and output a correlation value of the restored initial random access signal z(n) and the random access sequence RA_X having the maximum 45 correlation value within a reference range from the first time offset τ_c.

According to an embodiment, the reference range may be defined as in Equation 4 below.

$$\tau_c - T_L \leq \tau \leq \tau_c + T_R \qquad \text{(Equation 4)}$$

(where the T_L is a reference range of time fluctuation in the left direction, and the T_R is a reference range of time fluctuation in the right direction)

The peak detector **275-3** may calculate the second time 55 offset based on a point at which a correlation value of the correlator **275-2** becomes maximum within the reference range.

According to an embodiment, the first time offset may have a meaning as a rough time synchronization error 60 because an initial random access signal with a reduced amount of data is used, and the second time offset may have a meaning as a precise time synchronization error because an initial random access signal with the original amount of data restored is used. According to an embodiment, a time 65 synchronization error in the present specification may be the first time offset or the second time offset.

FIG. **7** is a flowchart illustrating a method of operating a communication system according to an embodiment of the present invention.

Referring to FIGS. **1** to **7**, in operation S**710**, the communication system **10** may extract an initial random access signal from an uplink signal in a first physical layer (e.g., the lower physical layer (low-PHY)) of a first communication node (e.g., the remote unit **100**).

According to an embodiment, the communication system **10** may extract the initial random access signal by performing low-pass filtering after frequency-shifting the uplink signal.

According to an embodiment, the initial random access signal may be a PRACH signal.

In operation S**720**, the communication system **10** may reduce a data amount of the extracted initial random access signal in the first physical layer (e.g., the lower physical layer (low-PHY)).

According to an embodiment, the communication system **10** may reduce the amount of data by downsampling the extracted initial random access signal.

In operation S**730**, the communication system **10** may calculate a time synchronization error using the initial random access signal with a reduced amount of data in the second physical layer (e.g., the upper physical layer (high-PHY)) of a second communication node (e.g., the distributed unit **200**).

According to an embodiment, the communication system **10** may obtain a first time offset using the initial random access signal with a reduced amount of data, and may obtain a second time offset using the first time offset and an initial random access signal with the original amount of data restored.

According to an embodiment, the time synchronization error calculated by the communication system **10** may mean the first time offset or the second time offset. While the present disclosure has been particularly shown and described with reference to embodiments thereof, it will be understood that various changes in form and details may be made therein without departing from the scope of the following claims.

The invention claimed is:

1. A method of operating a communication system using physical layer division, the method comprising:

extracting an initial random access signal from an uplink signal, in a first physical layer of a first communication node of the communication system;

reducing a data amount of the extracted initial random access signal in the first physical layer;

transmitting the initial random access signal with the reduced amount of data from the first communication node to a second communication node of the communication system; and

calculating a time synchronization error between the first communication node and the second communication node using the initial random access signal with the reduced amount of data, in a second physical layer of the second communication node,

wherein the calculating of the time synchronization error comprises:

calculating a first time offset using the initial random access signal with the reduced amount of data;

restoring the initial random access signal with an original amount of data by using the initial random access signal with the reduced amount of data;

calculating correlation values between the initial random access signal with the reduced amount of data and a plurality of random access sequences;

searching for a random access sequence having a maximum correlation value, among the calculated correlation values, from among the plurality of random access sequences; and

calculating a second time offset as the time synchronization error based on a point at which a correlation value of the restored initial random access signal and the random access sequence having the maximum correlation value becomes maximum within a reference range from the first time offset.

2. The method of claim 1, wherein the first physical layer is a lower physical layer according to the physical layer division, and

the second physical layer is an upper physical layer according to the physical layer division.

3. The method of claim 1, wherein the initial random access signal is a physical random access channel (PRACH) signal.

4. The method of claim 1, wherein the first communication node is a remote unit, and the second communication node is a distributed unit.

5. The method of claim 1, wherein the extracting of the initial random access signal from the uplink signal comprises:

shifting a frequency band of the uplink signal to a baseband; and

extracting the initial random access signal by low-pass filtering the frequency band-shifted uplink signal.

6. The method of claim 1, wherein the reducing of the data amount of the extracted initial random access signal comprises:

downsampling the extracted initial random access signal to reduce the data amount of the initial random access signal.

7. The method of claim 1, further comprising:

transmitting a combined signal generated by combining the uplink signal through data channel processing of the first physical layer in the first communication node and the initial random access signal with the reduced amount of data to the second communication node, and

the calculating of the time synchronization error comprises:

separating, by the second communication node, the initial random access signal with the reduced amount of data from the combined signal; and

calculating, by the second communication node, the initial time synchronization error using the separated initial random access signal with the reduced amount of data.

8. The method of claim 1, wherein the restoring of the initial random access signal with the original amount of data comprises:

upsampling the initial random access signal with the reduced amount of data; and

interpolating the upsampled initial random access signal.

9. The method of claim 8, wherein the interpolating of the upsampled initial random access signal comprises:

low-pass filtering the upsampled initial random access signal.

10. A communication node including a memory and a processor, wherein the communication node receives an initial random access signal with a reduced amount of data extracted from an uplink signal from another communication node, and calculates a time synchronization error between the communication node and the another communication node using the initial random access signal with the reduced amount of data in a physical layer of the communication node,

wherein the communication node is configured to:

calculate a first time offset using the initial random access signal with the reduced amount of data;

restore the initial random access signal with an original amount of data by using the initial random access signal with the reduced amount of data;

calculate correlation values between the initial random access signal with the reduced amount of data and a plurality of random access sequences;

search for a random access sequence having a maximum correlation value, among the calculated correlation values, from among the plurality of random access sequences; and

calculate a second time offset as the time synchronization error based on a point at which a correlation value of the restored initial random access signal and the random access sequence having the maximum correlation value becomes maximum within a reference range from the first time offset.

11. A communication system using physical layer division, the communication system comprising:

a first communication node configured to extract an initial random access signal from an uplink signal and reduce a data amount of the extracted initial random access signal in a first physical layer, and transmit an initial random access signal with the reduced amount of data to a second communication node; and

the second communication node configured to calculate a time synchronization error between the first communication node and the second communication node using the initial random access signal with the reduced amount of data in a second physical layer,

wherein the second communication node is configured to:

calculate a first time offset using the initial random access signal with the reduced amount of data;

restore the initial random access signal with an original amount of data by using the initial random access signal with the reduced amount of data;

calculate correlation values between the initial random access signal with the reduced amount of data and a plurality of random access sequences;

search for a random access sequence having a maximum correlation value, among the calculated correlation values, from among the plurality of random access sequences; and

calculate a second time offset as the time synchronization error based on a point at which a correlation value of the restored initial random access signal and the random access sequence having the maximum correlation value becomes maximum within a reference range from the first time offset.

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